WHAT ARCHIVED RUSSIAN DATA SAY ABOUT THE SURFACE HEAT BUDGET OF THE ARCTIC OCEAN

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LONG-TERM GOALS

Preparing for the SHEBA experiment requires optimizing limited resources and focusing the experimental plan on key deficiencies in current understanding of the heat budget of the Arctic Ocean. In this work we will review Russian literature—which is poorly known in the West—to confirm what is really known and what is not known, worldwide, about the Arctic heat budget. We will also obtain data from the vast archive from the Russian North Pole drifting stations and reanalyze some of these data in light of modern theories to confirm or expand Western analyses. Our goal from this research, as with the whole SHEBA program, is better understanding and parameterizations of processes that influence the surface heat budget of the Arctic Ocean.

OBJECTIVES

1. To review the scientific literature published in Russian that is relevant to our better understanding the surface heat budget of the Arctic Ocean;
2. To obtain from Russian archives and then to analyze data collected on several of the Russian North Pole drifting stations in light of current boundary layer theory and modern parameterizations of the relevant physical processes.

APPROACH

This is a collaborative study between Ed Andreas at CRREL and Aleksandr Makshtas of the Arctic and Antarctic Research Institute (AARI) in St. Petersburg, Russia. AARI is the archive for data from the North Pole drifting stations. Under contract with CRREL, Makshtas will oversee the conversion from the original hard-copy format to electronic format of special micrometeorological data collected on several of these stations and will be responsible for initial quality control. Makshtas will visit CRREL yearly to transfer data and to collaborate with Andreas on their analysis and interpretation.

Although some of these data were analyzed and reported in the Russian literature when they were collected, those reports were in Russian and the actual raw data were never made available to Western scientists. Also, some of the data on which we are focusing, for example those from North Pole 4, 5, and 6, were collected in the 1950s, before Monin-Obukhov similarity theory unified our understanding of the atmospheric boundary layer. Hence, we will, in effect, be analyzing old data with new theories.

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Rachel Jordan, also from CRREL, has developed SNTHERM, a sophisticated one-dimensional energy and mass-balance model for snow-covered surfaces. We will adapt SNTHERM to a sea ice environment and then use it to assimilate the North Pole time series data into an energetically consistent framework. In effect, we will be using the North Pole data to test SNTHERM's heat flux parameterizations while documenting the annual cycle of the components in the Arctic's surface energy budget.

ACCOMPLISHMENTS

Makshtas visited CRREL for six weeks in February and March 1997. He brought with him on floppy disks additional data from stations North Pole 4, 5, 6, and 28 that had been digitized from the AARI hard-copy archives. During his visit, we prepared a manuscript, "Accounting for Clouds in Sea Ice Models," based on the North Pole data and also on our Antarctic data. We have submitted this manuscript for publication in *Journal of Geophysical Research*.

During Makshtas's visit, we also did a lot of work on a second manuscript, "A Study of the Surface Heat Budget of the Arctic Ocean Based on Data from North Pole 4," that we will submit soon to *Journal of Geophysical Research*. In preparing this manuscript, we discovered some inconsistencies in the precipitation data reported from the North Pole stations. Since SNTHERM also tracks the mass of the snow and sea ice, it was important to resolve these questions before we went forward with publishing this study. Hence, on returning to St. Petersburg, Makshtas had his colleague N. N. Bryazgin, who had done much of the original precipitation analysis on the North Pole data, apply his correction factors to the reported North Pole precipitation data. Makshtas sent us these revised data, and we have incorporated them into SNTHERM's simulations.

One of our objects in this work was to lay foundation for Phase II of SHEBA, the year-long Arctic Ocean surface heat budget experiment. On the basis of some of the scientific issues we have encountered in our current analysis—e.g., the intractability of the very stable atmospheric boundary layer, the spatial variability in the surface heat fluxes, the bimodal distribution in Arctic cloud amounts, and the extreme spatial variability of snow depth—Andreas, Chris Fairall (NOAA/ETL), Peter Guest (Naval Postgraduate School), and Ola Persson (CIRES, University of Colorado) wrote a proposal for SHEBA Phase II experimental work that the National Science Foundation has chosen to fund.

One part of this new experimental work will be to deploy four NCAR PAM (portable atmospheric mesonet) stations around the main SHEBA camp to investigate the spatial variability of the surface fluxes. One idea was that wind power could be used to generate the electricity to run these remote stations. On analyzing a year of wind speed data from our North Pole 4 data set, however, we decided that Arctic surface winds were probably not strong enough nor persistent enough to provide the sustained power necessary to run the PAM stations. We thus chose thermoelectric generators to power the PAM stations. In other words, this current project directly and immediately benefited our preparations for Phase II of SHEBA, as we hoped it would.

Andreas has prepared two other manuscripts under this project. One is "The Atmospheric Boundary Layer over Polar Marine Surfaces" that will be published in a book on sea ice physics. Another is "Convective Heat Transfer over Wintertime Leads and Polynyas" that will be submitted for publication later this fall.

SCIENTIFIC RESULTS

Our manuscript, "Accounting for Clouds in Sea Ice Models," has two main results. The first is that cloud amounts over sea ice in both the Arctic and the Antarctic have U-shaped, bimodal distributions year-round. That is, cloud amount is usually either 0-2 tenths or 8-10 tenths: The sky is generally either clear or totally overcast. Most reported polar cloud statistics (e.g., those tabulated in the famous Russian atlases), however, are monthly averaged cloud amounts. Clearly, the average of a quantity with a U-shaped distribution will be the least likely value in the distirbution; for example, 5-6 tenths for the average polar cloud amount. Because the radiation components generally depend nonlinearly on cloud amount, using such averaged cloud amounts in models will adversely affect our understanding of the components of the Arctic heat budget.

The second interesting result in this "Clouds" paper is that, in the winter, cloud amount over sea ice is closely related to the near-surface air temperature. It is thus possible to predict cloud amount from the air temperature alone; we developed a statistical algorithm that does this. As a result, we point out that, coupled with data from the Arctic buoy network, for example, this algorithm can yield Arctic winter cloud amounts with a coverage typical of satellite observations.

Our paper on the surface heat budget of North Pole 4 introduces a new, ad hoc parameterization for estimating the turbulent surface fluxes in an intermittently turbulent boundary layer commonly found over polar marine surfaces. We call this effect 'windless transfer.' Although our computations using the North Pole 4 time series data support this parameterization, it has not been verified by direct measurements. Consequently, investigating this windless transfer became a focus for our Phase II SHEBA measurements.

In the paper on leads and polynyas, I present a new algorithm for estimating the turbulent sensible and latent heat fluxes escaping from these warm surfaces surrounded by sea ice. The rule of thumb is that, although open water may cover only 1-2% of the Arctic Ocean in winter, because of the large water-air temperature difference, leads and polynyas can transfer half of the heat that the ocean loses to the atmosphere. Thus, understanding how to estimate these heat losses is crucial. The benefit of this new parameterization is that it depends very weakly on wind speed (in contrast to the more standard bulk-aerodynamic formulation). This suggests the possibility of estimating sensible and latent heat losses from leads and polynyas from satellite data. Although satellites do poorly in yielding wind speed over sea ice, they can routinely provide measurements of lead and polynya size, their surface temperature, and the temperature of the surrounding sea ice surface—the key variables in this new algorithm.

IMPACT FOR SCIENCE

Stable boundary layers occur in lower latitudes, too, not just in the polar regions. In lower latitudes, however, stable boundary layers usually occur at night and, because of their slow evolution, are rarely fully developed. In the polar regions, on the other hands, stable boundary layers are common even during the day and, during the long polar night, can become quite well developed. In essence, then, polar regions are ideal for studying stable boundary layers; but results obtained here apply directly in lower latitudes, as well, where such studies are more difficult.

Our adapting SNTHERM to treat a sea-ice environment should really benefit the sea-ice community because of the model's sophistication and versatility.

We saw hints of the importance of windless transfer in very stable stratification in our analysis of the North Pole 4 data set. Recognizing this phenomenon has affected our planning for the SHEBA Phase II experiment: We have made investigating how to parameterize this windless transfer an experimental priority.

ONR's Marine Boundary Layer program has supported the RASEX experiment in the Kattegat off Denmark. The meteorological platform used for this experiment is in the sea about 2 km from land. When the wind blows from the land to the sea, a thin thermal internal boundary layer (IBL) develops that makes interpreting turbulence measurements made on the platform difficult. I have discussed this problem with Larry Mahrt of Oregon State; and we think the parameterization I developed for heat transfer over leads and polynyas—another situation characterized by an IBL—may yield insights into the Kattegat case. So, here again, Arctic measurements are providing insights for meteorological problems at lower latitudes.

TRANSITIONS

No significant transitions in FY97.

RELATED PROJECTS

Andreas has some in-house Army funding to study "Surface-Air Boundary Transfer Processes." That Army project and this ONR project focus on similar processes, though not necessarily in the same environment.

CRREL also cost-shared this work in FY97 by supplementing it with in-house funding for our study of "The Atmospheric Boundary Layer in Very Stable Stratification." These funds, in fact, not ONR money, paid for Rachel Jordan's FY97 participation in this project. And $3,000 from this in-house project were used to increase the AARI contract to have them reconsider the North Pole precipitation data, work not covered under the original AARI contract.

Andreas, with Fairall, Guest, and Persson, wrote a SHEBA Phase II proposal that was funded by NSF. Data transferred from AARI to CRREL and analysis performed under the current project helped us focus this Phase II work and plan the logistics.

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